ANALYSIS OF DESIGN CHANGES
ON NAVY CONSTRUCTION PROJECTS

APPROVED:

ANALYSIS OF DESIGN CHANGES ON NAVY CONSTRUCTION PROJECTS

by

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REPORT

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GLOSSARY OF TERMS

ARCHITECT/ENGINEER (A/E): Services for architectural and engineering design provided by consulting firms contracted by the Navy.

COMMERCE BUSINESS DAILY (CBD): A publication that NAVFAC uses to advertise for either engineering or construction services.

DEFENSE ACQUISITION REGULATIONS (DAR): The regulation used by the Department of Defense (DoD) for the acquisition of goods and services prior to 1984 which was replaced by the Federal Acquisition Regulations (FAR).

DEFENSE CONTRACT AUDITING AGENCY (DCAA): An agency set up by the Department of Defense (DoD) to conduct audits of companies that do business with DoD. DCAA performs audits of engineering and construction firms for the Navy.

DEPARTMENT OF DEFENSE (DoD): A major administrative division of the federal government that is responsible for the defense of the United States. This includes four military divisions: Army, Air Force, Navy, and Marine Corps.

DSGN: The reason code used by NAVFAC for contract modifications that were a result of design error or omission. This code is used when the A/E is not liable for the change.

ENGINEERING FIELD DIVISION (EFD): A regional subdivision of NAVFAC which is responsible for the planning and execution of the MILCON program within their region.

EROM: The reason code used by NAVFAC for contract modifications that were a result of a design error or omission. This category is used when A/E liability has been determined.

FEDERAL ACQUISITION REGULATIONS (FAR): The primary regulation used by all Federal Agencies conducting acquisition with appropriated funds. The FAR includes the regulations governing the procedures for A/E and construction acquisition.

FEE NEGOTIATION BOARD: The board at the EFD that is responsible for negotiating the design fee for Architectural/Engineering services.

MILITARY CONSTRUCTION (MILCON) PROGRAM: The program used by the Department of Defense for capital improvements for their shore facilities. All construction projects costing in excess of $200,000 are included in the program which is authorized annually by the

Congress as part of the federal budget.

NAVAL FACILITIES ENGINEERING COMMAND (NAVFAC): The organization within the Navy which is responsible for maintenance for all Naval shore facilities.

PUBLIC WORKS DEPARTMENT: The department located at a Navy base that is responsible for maintenance of the base facilities. The department has an engineering division that is responsible for identifying projects that will become a part of the MILCON program. The engineering division also performs reviews of A/E's plans and specifications.

RESIDENT OFFICER IN CHARGE OF CONSTRUCTION (ROICC): The field office established by the EFD to administer the construction contracts after award. The ROICC is responsible for all construction contracts regardless of dollar amount.

SELECTION COMMITTEE: A committee of engineers and architects at the EFD that reviews A/E firms proposed by the Slate committee and selects the top firms and ranks each firm by order of preference.

SLATE COMMITTEE: A committee of engineers and architects at the EFD that reviews all interested A/E firms for a particular project. The

slate committee uses a set of criteria to determine which firms are best qualified and forwards the list of firms to the selection committee.

SOUTHERN DIVISION: A division of NAVFAC that is responsible for the execution of MILCON projects from conceptual planning to start-up. Southern Division is responsible for the award and administration of A/E contracts and the award of construction projects.

STANDARD FORM (SF) 254 : The SF 254 is a general resume of a design firm's experience. The firm must list the number of design personnel by discipline, gross design fees for the past five years, and a list of projects performed in the past five years. A firm is required is submit the form to be considered for future contracts to do design work for NAVFAC.

STANDARD FORM (SF) 255: The SF 255 is a statement of specific qualifications for a particular design project. The firm must submit additional information such as: any joint-ventures for the projects, outside key consultants, and a brief resume of all key personnel that will work on the project. The form is required if the design fee exceeds $25,000.

UNFO: The reason code used by NAVFAC for contract modifications that were a result unforeseen conditions. This code is used when the A/E could not have been expected to know the existing conditions when the design was performed.

CHAPTER 1
INTRODUCTION

1.1 PURPOSE

The purpose of this research was to investigate design related changes on Navy construction contracts. With the results of this study, it is hoped that the Navy can improve on certain areas of design review in order to minimize the number and cost of design changes on future construction projects.

1.2 SCOPE

This research included the study of design related contract modifications on 23 construction projects located in the Southeastern part of the United States. Southern Division, Naval Facilities Engineering Command, provided copies of the construction contract changes that were related to design which included an error or omission in the design and unforeseen conditions relating to design. These changes were then categorized by the engineering discipline responsible for design and then quantified by number and cost for each category. They were further categorized by the type of design deficiency, i.e. incorrect dimensions or sizes, incorrect details, interferences, omissions and revisions. The analysis then focused on

how to improve design reviews by both the Architectural/Engineering (A/E) firm and Southern Division. Ideally, if the A/E conducted appropriate in-house reviews, additional reviews by the Southern Division should practically eliminate design changes that occur during construction.

CHAPTER 2

THE NAVY AS AN OWNER

2.1 ORGANIZATION

The Department of Defense is organized into four branches; Army, Air Force, Navy and Marine Corps. The Department of Defense (DoD) has established a program for capital improvements called the Military Construction Program (MILCON). For fiscal year 1992 (FY 92), the military construction budget was $3.46 billion for military housing and $3.98 billion for all remaining construction.[1] The Army and Navy are responsible for execution of the MILCON program and oversee construction at Air Force and Marine Corps bases. The Navy's portion of the budget is approximately $2 billion per year.[2] The MILCON program applies to projects that exceed $200,000 in construction cost. These projects include administrative and training facilities and there are also requirements to provide facilities for logistics, communications and personnel support facilities such as commissaries, exchanges, and recreational facilities. This program replaces old and inefficient facilities and provides facilities needed because of new or revised missions for the operating forces. The Navy is broken into various major claimants,

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[1] Senate Hikes Transportation Funds: Panel Keeps Steady on Military, Engineering News Record, Vol 227, No. 12, 23 Sep. 1991, p. 7.

[2] James A. Broaddus, Design Effectiveness in Construction: The Relationship Between Inputs to the Design Process and Project Success, Ph.D. Dissertation, University of Texas at Austin, 1991, p. 30.

one of which is the Naval Facilities Engineering Command (NAVFAC). NAVFAC is assigned the responsibility for maintaining the assets of the naval shore facilities and manages the MILCON program for the Navy. Figure 2-1 shows how NAVFAC fits into the Navy and DoD organization.

NAVFAC is organized into eight geographical Engineering Field Divisions (EFD). These field divisions handle the execution of the projects from conceptual planning to start-up. Other areas under NAVFAC's command includes several Public Works Centers (PWC's) located at larger Naval installations. NAVFAC also commands the Naval Civil Engineering Laboratory (NCEL) located in Port Hueneme, CA. which conducts research for the Navy and the Naval Construction Battalion Centers (NCBC) which is responsible for the Navy Seabee's.

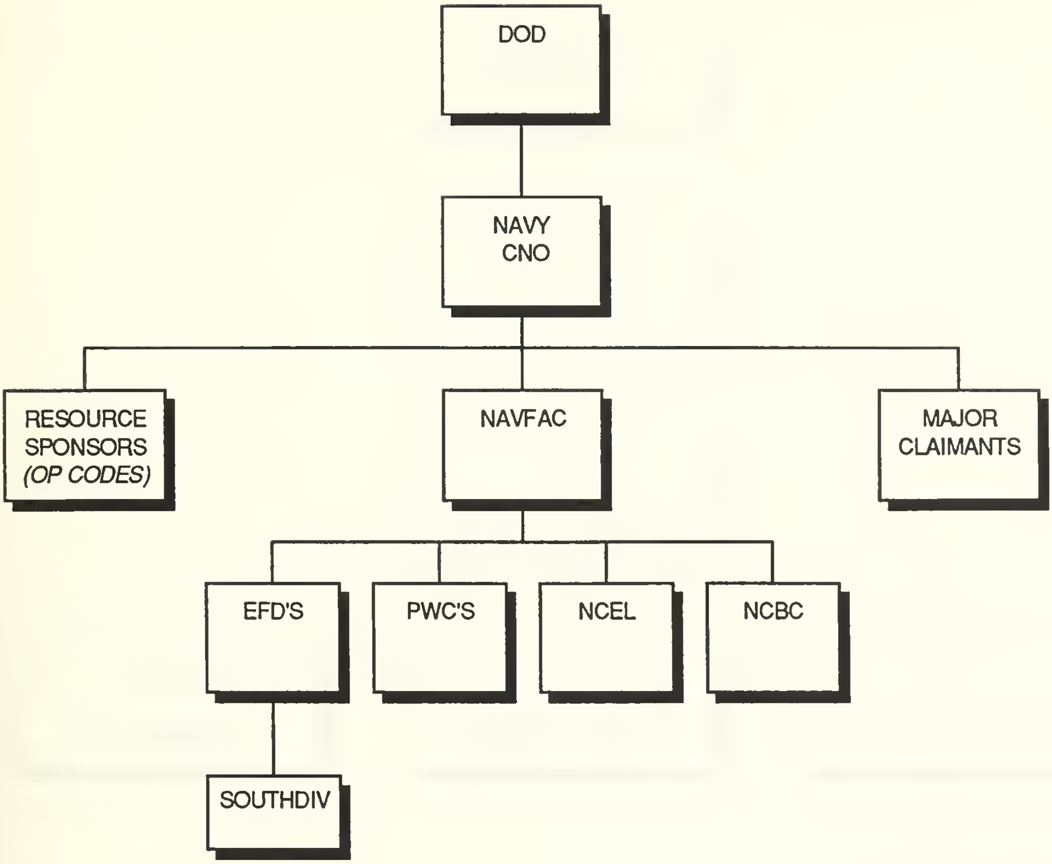

Figure 2-1: NAVFAC Organization

The contract change orders used in this research came from the Southern Division of NAVFAC. Figure 2-2 shows Southern Division's organization (some departments of the EFD are omitted for clarity). These change orders were from construction contracts that cover the geographical region of the southern United States from South Carolina to New Mexico.

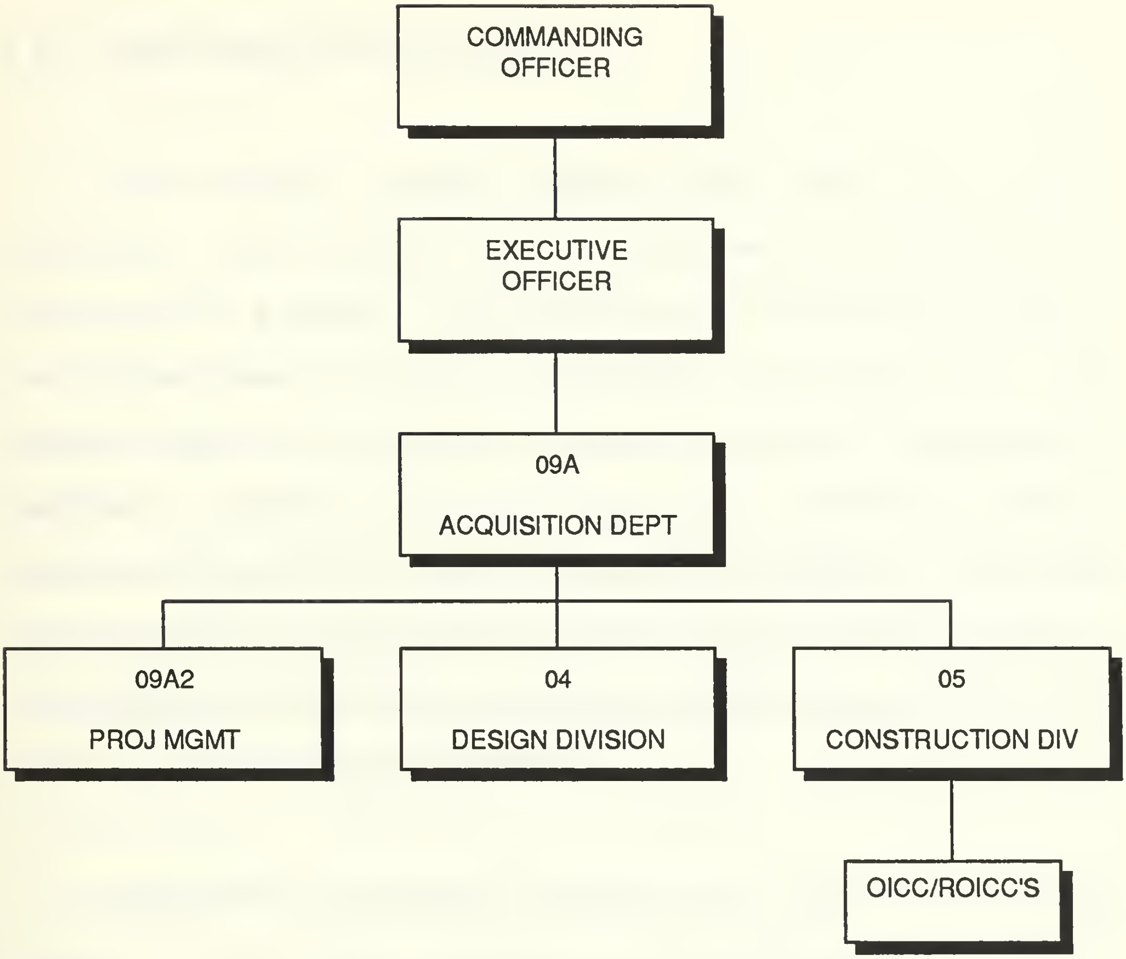

Figure 2-2: Southern Division Organizational Chart

The EFD is further subdivided into field offices entitled (ROICC'S) which handle the administration of the construction contracts after award. These offices consist of engineers (both civilian and military), inspectors and contract administrators. Each project is assigned to a team which consists of one member from each specialty.

2.2 CONSTRUCTION PROCESS

The MILCON process begins years before any actual construction work is done on site. It starts when an activity has a requirement for a facility. This requirement can be generated locally at the affected base, or it may be generated by the needs of a new weapons system or a change in mission. After the requirement is identified, a project is submitted through the operations chain-of-command to the Chief of Naval Operations for validation. The project request includes a brief description of the scope and estimated costs. If the project is validated and is of high priority, it will become a part of the Six-Year Defense Program (SYDP).[3]

Not all Navy construction projects are a part of the MILCON process. In some cases, operations and maintenance funds may be used for construction, but the most complex and expensive projects performed are a part of the MILCON program. The process is very competitive given the limited amount of funds available each year for overall defense spending.

When a project is within three years of its budget year, the planning process begins in earnest. The scope is further defined so that there is sufficient information available to proceed with design

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[3]Stephen S. Bell, Design Input Index as a Predictor of Project Change Behavior, Master's Departmental Report, University of Texas at Austin, 1991, p. 6.

authorization. In this stage, the EFD Planning Department has control of the project. Once the project is "Certified Ready for Design" and the project is within two years of its budget year, design of the project can begin.[4]

The selection of the project A/E is based on qualifications contained in the Brooks Act, which is discussed in the next chapter. After the contract is negotiated, the A/E can begin work on the detailed design. This period of the project is critical. The A/E must have 35 percent of the design completed by the September that is 14 months before the project's scheduled budget year. If this milestone is not met, the project will either be pushed back two years or it may be cancelled in its entirety. This situation is controlled by Congressional requirements.[5]

With 35 percent of the design complete, the project goes into the President's budget submission to the Congress as part of DoD's budget request. It must then go through hearings before a number of committees within both houses of the Congress. If the project survives as a part of the Congressional budget process and is passed into law, the Navy can enter into a contract to build the project.[6]

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[4]Bell, p. 6.
[5]Ibid., p. 7.
[6]Ibid., p. 7.

2.3 CONTRACTING

There are several documents that implement Federal laws relating to design construction within NAVFAC. These documents are part of a hierarchy, with the first having the greatest power and the most generality. The lead document is the Federal Acquisition Regulation (FAR). This regulation governs all Federal procurements and was enacted in 1984 to replace the Defense Acquisition Regulations (DAR). The Department of Defense has a supplement to the FAR which publishes specific regulations pertaining to the DoD (DFARS). NAVFAC has its own Contracting Manual (P-68) which contains specific regulations applying to NAVFAC procurement. The standard method of contracting for both A/E services and construction is the fixed-price contract.

Contracting for A/E services is a complex procedure that is regulated by the FAR. The next chapter will discuss in greater detail the process of selecting an A/E firm.

For construction, the process is simpler. Construction contracts are competitively bid, fixed price contracts. Any contractor with sufficient financial backing may bid on government contracts. The solicitation typically requires the contractor to submit performance,

payment and bid bonds. The government has established a special program called the Small Business Administration (8a) program which specifically seeks minority contractors. Those contracts are called (8a) set-aside and only members of the program are allowed to either bid or negotiate for those contracts. Before 1988, most construction contracts were set aside for only small businesses (which were businesses that had an average annual income of less than $17 million). The (8a) program still exists and is used for a few contracts; however, the remaining contracts can now be bid on by all contractors.

Southern Division handles the administration of design contracts for MILCON projects. For construction, Southern Division handles the advertisement and award of the construction contracts and the ROICC office handles the post award administration of the contracts.

2.4 CHANGE ORDER PROCESS

Change Orders in the private industry are referred to as "contract modifications" by the government. A modification is contractual guidance provided to the contractor by the owner. These changes typically concern the specifications and drawings. Changes can involve addition of work, deletion of work, rework, or change in material or

equipment furnished.[7] The government had established a formal procedure to process changes. The contract documents will contain a change clause or other clauses pertaining to changed conditions. The process is started when a reason for a change is identified. A contractor may identify design errors or omissions that will not allow for the completion of the work. The ROICC project engineer will then identify the scope of the change and determine if additional funds are necessary. If so, a formal request is sent to Southern Division Construction Area Manager (Code 05) explaining the reason and scope of the change and a preliminary estimate. Southern Division has established a listing of construction contract reason codes for modifications on both A/E and construction contracts. The codes used for this research are explained in section 2.5 of this chapter. The ROICC project engineer initially assigns a code that is sent with the request. This code will be discussed in more detail later in the chapter. If the change is complex, it may require input from the A/E to assist in design revisions.

When funds for a change are established, the Navy asks the contractor for a formal proposal to perform the change. The contractor prepares an estimate of the proposed cost and submits it to the government. The government then performs an analysis of the

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[7]Construction Industry Institute Cost/Schedule Controls Task Force, The Impact of Changes on Construction Cost and Schedule, Publication 6-10 (Austin, TX: Construction Industry Institute, 1990), p. 3.

contractor's proposal. If the contractor's proposal is fair and reasonable, a contract modification is issued. This seldom occurs and negotiations are typically conducted to determine a price for the change. Once negotiations are complete, the ROICC office issues a contract modification that is signed by both the contractor and ROICC contracting officer.

2.5 CONSTRUCTION MANAGEMENT SYSTEM

Southern Division has developed a construction management system to monitor the progress of all active construction projects. The system is basically an accounting system that allows tracking of progress payments and modifications to the contracts. When a modification is made, a reason code is assigned to the modification. These codes apply to both A/E and construction contracts. Design related changes for construction contracts typically fit one of three reason codes: UNFO, EROM, or DSGN.

The category "UNFO" covers unforeseen conditions. Such conditions typically occur when a designer cannot identify a potential problem during design, such as caused by a lack of site visitations or incorrect "as-builts". The "EROM" or DSGN" codes also cover design errors or omissions but "EROM" is used if the A/E is liable or potentially

liable for paying for the cost of the change. The code "DSGN" is used if the A/E is not considered liable for the change.

This distinction creates a potential problem for the ROICC office which is charged with execution of a change order. The ROICC office must make a determination or question whether the A/E is liable. The ROICC office is concerned with executing the modification as quickly as possible to avoid additional costs of delays to a contractor. The liability issue usually hinges on whether the change will require removal and rework of the contractor's existing work. If the design error is corrected prior to work associated with the error beginning, the A/E is usually not liable. The reason is that the government would have to pay for the work as if it had been included with the original plans and specifications. In order to expedite issuance of funds to the field office, the Southern Division Construction Area Manager or ROICC might change the codes to "UNFO" to eliminate the need to determine whether the A/E is liable. For this reason, modifications coded "UNFO" were included in this research if they involved design changes.

CHAPTER 3

DESIGN MANAGEMENT

3.1 INTRODUCTION

Design is a subjective process used by engineers and architects to transcribe ideas and information to paper in the form of specific and coordinated instructions for the construction of a specific project.[8] NAVFAC is given the responsibility to design billions of dollars worth of military projects for the Navy, Marine Corps and the Air Force. NAVFAC has delegated the design responsibilities to each of the Engineering Field Divisions (EFD). Each EFD contains a design branch that performs some designs in-house. In-house designs only accounts for less than 20% of the total design effort with the remaining effort being done by private A/E consulting firms contracted by the EFD.

According to public law 92-582, enacted in 1970, commonly referred to as the "Brooks Bill":

> "it is the policy of the Federal Government to announce all requirements for architectural and engineering services, and to negotiate contracts for A/E services. On the basis of demonstrated competence and qualification for the type of

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[8]Construction Industry Institute Design Task Force, Evaluation of Design Effectiveness, Publication 8-1 (Austin, TX: Construction Industry Institute, 1986), p. 1.

> professional services required and at fair and reasonable prices."[9]

This law also defines A/E services as "the professional services of an architectural or engineering nature as well as incidental services that members of these professions and those in their employ may logically or justifiably perform." Even before this law was enacted, the Navy was authorized to seek A/E services from outside firms. With the advent of WWII in Europe in 1939, the military branches could not hire enough in-house architects and engineers. As a result, the Public Works Act of 1939 which is now codified in 10 USC 7212 authorized the Navy to seek outside A/E services to produce designs, plans, drawing, and specifications for the accomplishment of any naval public works or utility project. The statute also imposed a maximum design fee of 6 percent of the estimated construction cost.[10] That design fee limitation still exists today. Procurement and administration of A/E services is also regulated by the Federal Acquisition Regulations (FAR) and the Department of Defense FAR Supplement. This process of procurement and administration of A/E services will be detailed later in this chapter.

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[9] Student Guide for Design Contract Management, Naval Facilities Contract Training Center, Port Hueneme, CA., Section 2202-1, p. 2.

[10] Student Guide for Design Contract Management, Naval Facilities Contract Training Center, Port Hueneme, CA., Section 2206-1, p. 1.

3.2 A/E SELECTION PROCESS

Each EFD has specific policies and procedures for selection of A/E services. The first step is to determine an estimated cost for design services. If the cost of the services is expected to exceed $10,000, the contract must be synopsized and announced in the Commerce Business Daily (CBD). The synopsis is a general description and scope of the project.

When an A/E firm wants to do business with the government, it must submit an SF 254 and SF 255. The SF 254 is a general resume of the firm's experience. This form lists the number of employees in each type of discipline and the firm's design fee income for the last five years as well as examples of design projects over the last five years. The SF 255 is a statement of specific qualifications which is submitted for a particular contract. This form has the same general data as the SF 254 and, in addition, has a brief resume of the key personnel that will be assigned to the project and any subcontracts or joint ventures with other design firms.

The EFD will assign a Slate Committee to review the A/E firms that are interested in a particular design contract. The slate committee is typically made up of three members, preferably with engineering or architectural experience and with professional licenses. The committee

will set up evaluation criteria in order to identify the most qualified firm. The criteria should include the following:

(1) Qualifications of the A/E's design professionals;

(2) Recent similar experiences of the designers;

(3) Ability to meet design schedule of start and completion;

(4) Geographic location - i.e., distance from the construction site;

(5) Past experience on DoD contracts, review A/E evaluations; and

(6) Cost control methods used during design and bidding.

The criteria must also be included when the synopsis is submitted to the Commerce Business Daily (CBD). The Slate Committee will then evaluate the A/E firms. Special consideration will be made to "spread the work". FAR, NAVFAC and DoD policy dictate that even though consideration will be given to experience and satisfactory performance, an attempt must be made to bring in new and minority firms. The slate committee will forward a written report listing at least three recommended firms, along with details about each firm to a Selection Committee.

The Selection Committee is also composed of three professionals, but none of the Slate Committee members can serve on the Selection Committee. The Selection Committee cannot add or

delete firms from the list which the slate committee has recommended. The Selection Committee will review the report from the Slate Committee and then conduct interviews with the firms. The interviews can be conducted either by telephone or in person, depending on the estimated design fee. The Selection Committee members will then list, by secret ballot, the firms they feel best meet the selection criteria and alternates in order of preference for the firms. The Selection Committee then prepares a written report listing the firms and an explanation of why the top firm was selected over the others.

A Fee Negotiation Board is then established and sends the highest rated A/E firm a formal request for a proposal. The A/E must submit a detailed cost estimate to the Fee Negotiation Board. The A/E's proposal must be broken down into direct labor hours, labor rates, material, subcontracting cost, overhead and profit. The direct costs are further subdivided by engineering discipline. When the A/E's fee is received, it is compared to the government estimate which is also broken down into the same detail. If the A/E proposal is in excess of $100,000, the government will prepare a business clearance and request an audit of the A/E's proposal by the Defense Contract Auditing Agency (DCAA). After the reports are prepared, negotiations are conducted and a fee is agreed upon. Due to budget constraints, items of work may be deleted or reduced in scope during negotiations in order to stay below the 6% design fee cap. The items that might be deleted to

stay below the 6% cap include coordination reviews and reflected ceiling plans.

Certain items are not included when computing the maximum 6% fee. These include cost for site investigations, approval of shop drawings and submittals, preparation of as-builts, site surveys, soil investigations, travel expenses and reproduction of drawings. In order to keep the design fee to a minimum, these items might also be deleted or reduced from the initial scope of the project. If negotiations are unsuccessful, the board then prepares to negotiate with the second A/E firm. A Board does not have the power to award the A/E contract but makes a recommendation to the contracting officer who must sign the contract documents.

Once the A/E fee is agreed to, a fixed price contract is awarded to the A/E for the design of the facility. As shown by the influence chart in figure 3-1[11], the ability to control the cost of the project is higher in the early stages of the project. Attempts to try and save money up front can result in additional cost later in the project. An A/E firm must design the project to fit within the budgeted cost or redesign of the project will be required and the A/E will not receive any additional funds to cover the redesign.

[11]Construction Industry Institute Cost/Schedule Task Force, Model Planning and Controlling System for EPC of Industrial Projects, Publication 6-3 (Construction Industry Institute, 1987), p. 4.

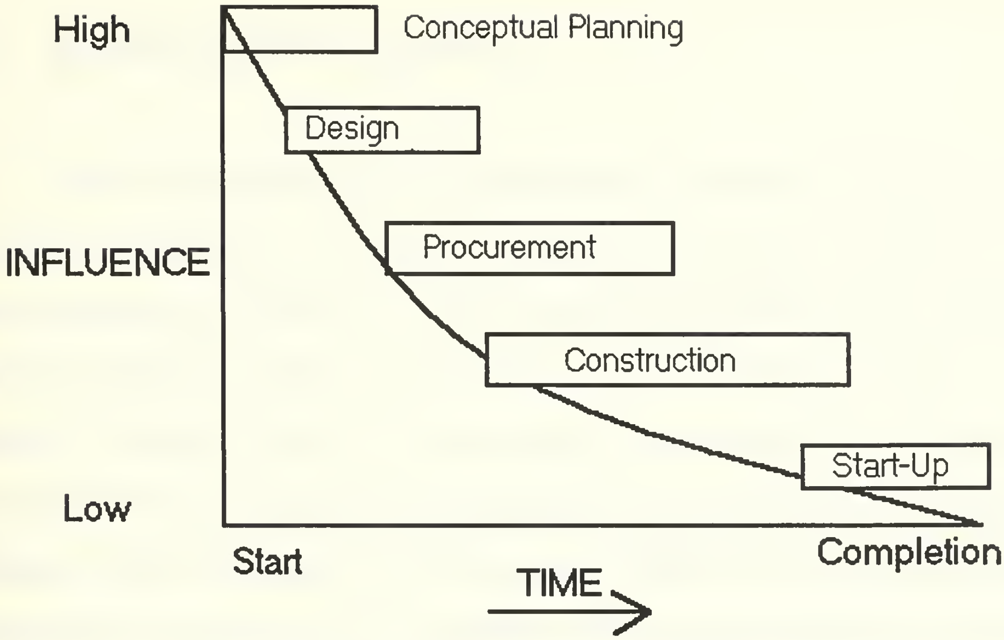

Figure 3-1: Cost Influence Curve

3.3 DESIGN PROCESS

The lead designers for the A/E will meet with the Engineer-in-Charge (EIC) and Project Manager of Southern Division to discuss the scope, schedule and items needed for design. The A/E will then visit the site and the Public Works Department at the base where the facility will be constructed to obtain site information on existing utility locations and "as-builts" of existing facilities if needed. The A/E will then proceed with the design to the 35% complete level.

3.4 DESIGN REVIEW PROCESS

Due to escalating cost of construction, it has been mandated that projects be designed, bid and constructed as rapidly as possible, as was discussed in Chapter 2. This schedule emphasis exerts pressure toward maximum speed and efficiency of the design process. To maintain quality, reviews of the design are necessary in order to minimize the cost of changes and claims during construction. Southern Division has developed an instruction (SOUTHNAVFACENGCOM Instruction 11012.10C) as a guideline for the responsibility for design reviews. This instruction covers technical, functional and constructability reviews.

The A/E's design is reviewed at 35%, 100% and at final completion. At each stage, the A/E sends sets of plans and specifications to be reviewed, except that the specifications are not required for the 35% design review. These items are sent to the Public Works Department at the base where the construction will be performed, the ROICC office at the base, Southern Division Design and Construction Branch, and the Major Claimant who is responsible for the facility. These parties are given approximately 10 working days to review the plans and specifications. Each reviewer's comments are then forwarded to the Engineer-in-Charge (EIC) at Southern Division, who forwards the comments to the A/E.

At Southern Division, the design branch performs a technical review of the plans and specifications and makes a list of review comments. At the ROICC office, the project engineer and inspector will review the plans and specifications for constructability. The construction branch at Southern Division also performs a constructability review.

The Public Works Department and the Major Claimant are responsible for the functional review of the project. It is important that this review is conducted no later than the 35% review stage since it can have a major impact on construction cost. This review should ensure the design has captured the intended scope of the project in order to eliminate future customer requested changes.

For projects with an estimated cost in excess of $2 million, a value engineering review is performed by an independent A/E firm hired by Southern Division. The design A/E will perform a coordination review of the plans and specifications, if required by contract. The A/E then forwards the coordination review results to Southern Division for verification that the review was performed. This process results in a much larger number of technical reviews of the designs than would be done in the private sector.

There currently exist two documents that are available as a checklist when performing design reviews. The first is the "Redicheck Plan and Specification Review" which was developed by Lieutenant Commander William T. Nigro.[12] This review method is aimed at eliminating mistakes that occur between coordination of different design disciplines. The review method also recommends that experienced engineers should perform the reviews rather than inexperienced personnel. The other method of review is the NAVFAC P446 publication entitled "Constructability Reviews." The publication is formatted similar to a set of specifications in that review questions are categorized according to the Construction Specifications Institute (CSI) format for specifications.

After review at the final stage, Southern Division will solicit and award a contract for construction. During the construction phase, the A/E may be required by contract amendments to perform additional work such as review and approval of shop drawings and providing inspection services. As part of the A/E's contract, if a design deficiency is found during construction, the A/E must provide revisions to the design at no additional cost to the government.

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[12] Student Guide for Design Contract Management, Naval Facilities Contract Training Center, Port Hueneme, CA., Section 2208-1, pp. 1-4.

CHAPTER 4
RESEARCH METHODOLOGY

4.1 INTRODUCTION

The projects selected to be studied were included in an earlier study by James Broaddus for his Ph.D. dissertation at the University of Texas at Austin. His research included a total of 55 projects, of which 23 projects had the necessary data to perform this further study. The 23 projects had construction costs of at least $2 million each and averaged approximately $5 million each. All of the projects were completed before this research was begun.

4.2 DATA GATHERING

The contract modifications for each project were reviewed and those relating to design were selected for the study. The Navy uses a method of numbering all plan sheets by the use of a letter representing the design discipline responsible for the drawings on that particular plan sheet along with the sheet number. Some modifications referenced plan sheets and/or the specifications which enabled the modification to be properly categorized. For the other modifications, the description of the work entailed enabled the modification to be categorized by the engineering discipline that was responsible for the design. Each

modification was also categorized by the reason for change. The following five reasons were used: (1) incorrect dimensions or sizes, (2) incorrect details, (3) interference, (4) omission and (5) revision.

The data were then quantified both by number of changes and cost of the changes to each category. It should be noted that some ROICC offices combined two or more design changes on the same modification. There were 242 contract modifications with a total of 292 design changes for the 23 projects. A listing of the data is available in the appendix. For the purpose of this research, each design change was counted individually. Some of the modifications resulted in a deductive amount but for this research all cost were taken as an absolute valve and then tabulated. The deductive amounts were only a small amount of the total dollar volume of all the modifications. For additional information, the number of extra days granted for a time extension to complete each project was also tabulated.

CHAPTER 5
ANALYSIS OF DATA

5.1 INTRODUCTION

The results of the analysis is shown for each design discipline. For each design discipline, the modifications were quantified by number and cost for each type of reason the modifications were issued. The percent of changes and percent of cost were also calculated based on the total number and cost of changes for each design discipline. In addition, the average cost per change for each of the reasons was calculated along with the average cost per change for all the changes for each design discipline.

5.2 ARCHITECTURAL CHANGES

There were a total of 60 architectural design changes that cost a total of $355,499. A summary of the analysis of the architectural changes is shown in Figure 5-1. The majority of the architectural changes were due to omissions, which accounted for both 62% of the number of changes and 63% of the cost of the architectural changes. Figures 5-2 and 5-3 show the percent of changes and cost for architectural changes. Architectural changes averaged approximately $6,000 each with revisions having the largest average (above $9,000).

Reason for Change	No. of Changes	% of Changes	Total Cost	% of Cost	Avg. Cost per Change
Dimension	7	12	$14,060.00	4	$2,009
Detail	5	8	$17,945	5	$3,589
Omission	37	62	$223,876	63	$6,050
Revision	11	18	$99,618	28	$9,056
Total =	60	100	$355,499	100	$5,925

Figure 5-1: Architectural Changes

The architectural dimensions and size errors comprised two types of changes. The first type is changing or adding additional hardware for doors. Four of the 7 changes involved door hardware. The remaining 3 changes were due to building number signs being of the wrong size for all new buildings located at Naval Station, Ingleside. This latter category could have been included with revisions.

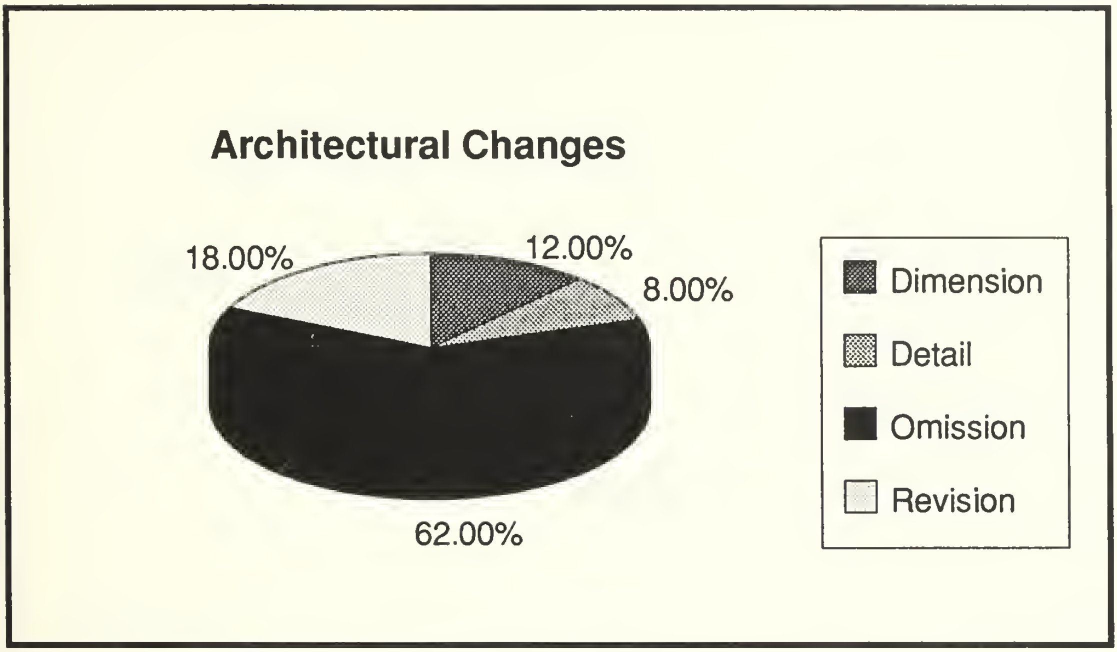

Figure 5-2: Percent of Architectural Changes

The 5 changes for architectural detail changes were not similar. The most costly was adding a wood nailer to a roof to match the cricket, which cost $8,671.

The 37 architectural omission changes accounted for the most changes in the architectural section. Of the 37 changes, 13 of these were related to doors and door hardware, and totaled $96,404. The only other major item was roofing, where 3 changes occurred costing $43,746. The remaining changes covered all areas of architectural including painting, fencing, ceiling and floors.

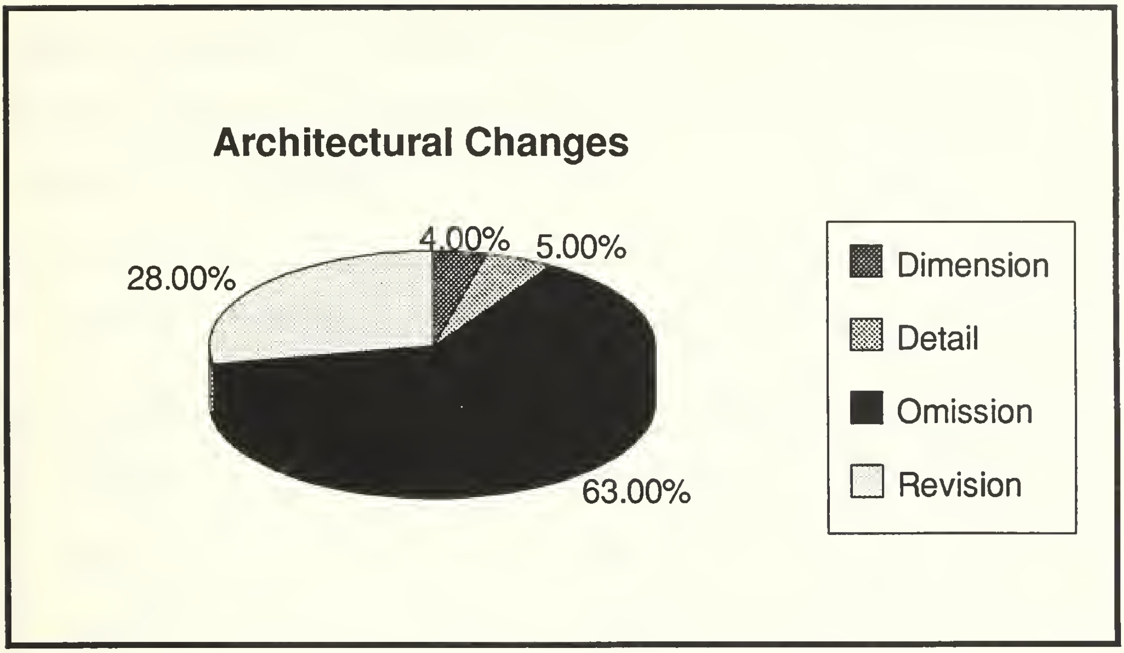

Figure 5-3: Percent of Cost for Architectural Changes

The architectural revision changes had a total of 11 changes. The most expensive of these was 2 changes to remove existing vinyl floor tile for the installation of new carpet which cost $46,000. The remaining changes include 2 changes for removal of asbestos and 2 changes for modifying the ceiling.

5.3 CIVIL CHANGES

There were a total of 44 civil changes that cost a total of $292,841. A summary and a breakdown is shown in Figure 5-4. The changes due to revisions accounted for over 50% of the changes and over 70% of the total costs for civil change orders. Figures 5-5 and 5-6

show the percent of changes and cost for civil changes. The civil changes orders averaged $6,655 each with revisions having the largest average (at over $9,000).

Reason for Change	No. of Changes	% of Changes	Total Cost	% of Cost	Avg. Cost per Change
Dimension	3	7	$5,667.00	2	$1,889
Interference	3	7	$4,345	1	$1,448
Omission	15	34	$75,536	26	$5,036
Revision	23	52	$207,293	71	$9,103
Total =	44	100	$292,841	100	$6,655

Figure 5-4: Civil Changes

The civil dimensions and size error changes contained 3 changes which were all related to changing the elevation and size of storm drain piping.

The civil interference changes contained 3 changes which required re-routing of underground piping and cable. Two of the changes were for sanitary sewer lines and the other was a telephone cable.

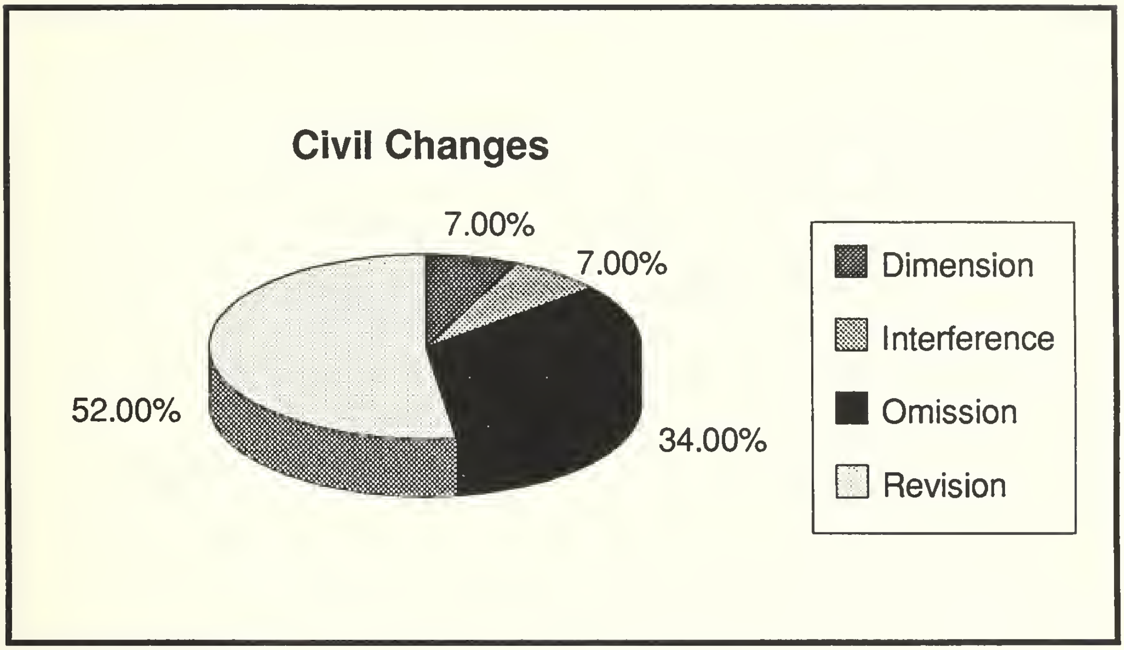

Figure 5-5: Percent of Civil Changes

The civil omission changes can be categorized in two areas, one being utilities and the other paving. There were a total of 15 changes involving the addition of utility piping, manholes and valves. A total of 7 of these involved water lines, three involved sanitary sewer lines and the remaining were for storm drain lines. There were 4 paving changes included the addition of a driveway, extension of a curb and additional base and paving material that was necessary.

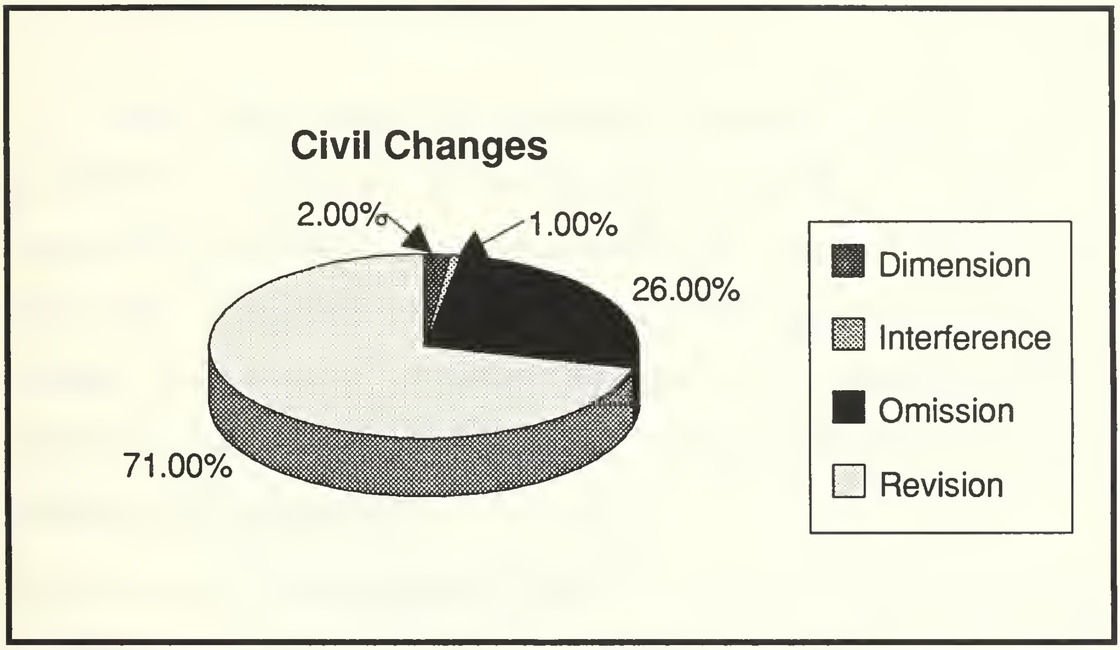

Figure 5-6: Percent of Cost for Civil Changes

The civil revision changes contained 23 changes of which 12 were related to unsuitable soils. These changes cost $207,293 which was an average of over $9,000 each. These changes typically involved removal of unsuitable material and replacement with suitable fill material. The other area of changes also included revisions to underground utility lines of which there were 7 changes totalling $36,672. These usually required the re-routing of piping which may have been caused by interferences but that reason could not be confirmed.

5.4 STRUCTURAL CHANGES

There were a total of 57 structural changes that cost a total of $1,666,986. A summary of the breakdown is shown in Figure 5-7. Omissions accounted for the most changes, 51%, but revisions cost the most, 63%, of the total cost. Figures 5-8 and 5-9 show the percent of changes and cost for structural changes. The average cost for structural changes was $29,245 with revisions having the largest average (at over $55,000).

Reason for Change	No. of Changes	% of Changes	Total Cost	% of Cost	Avg. Cost per Change
Dimension	5	9	$60,580.00	4	$12,116
Detail	4	7	$12,632	1	$3,158
Omission	29	51	$530,179	32	$18,282
Revision	19	33	$1,063,595	63	$55,979
Total =	57	100	$1,666,986	100	$29,245

Figure 5-7: Structural Changes

The structural dimension and size error changes involved the changing of sizes which typically caused an increase in size. The most costly of these changes was for $23,927 which required changing the

size of washers on an antenna. The other major one required increasing the size of bar joists for the roof.

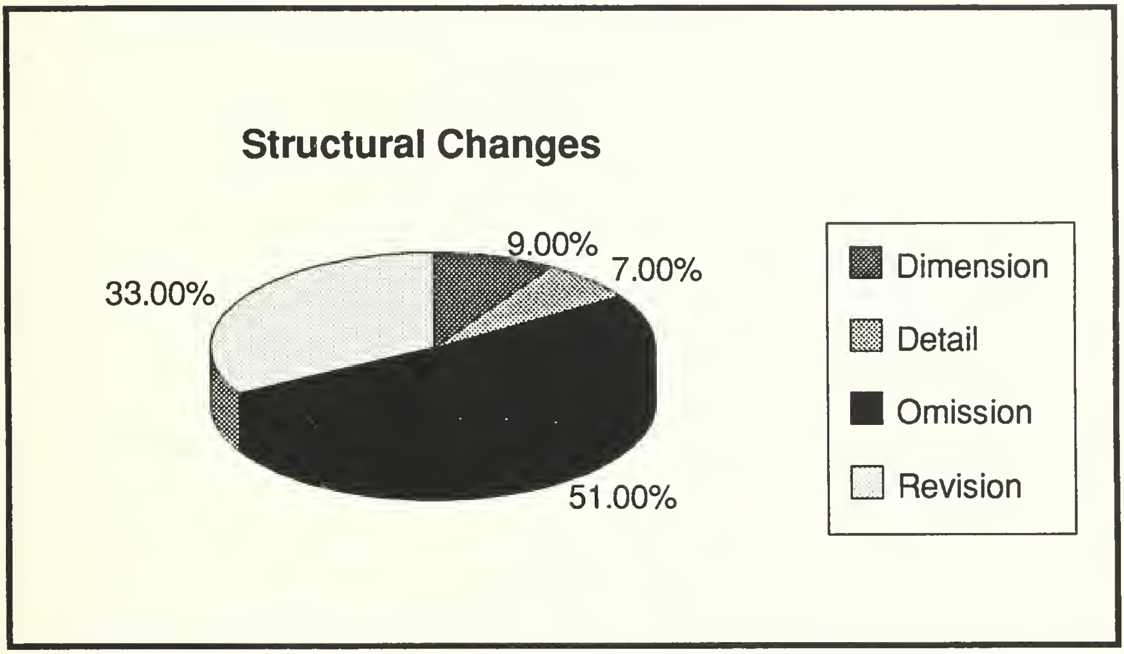

Figure 5-8: Percent of Structural Changes

The structural detail changes involved 4 changes of which 2 were related to structural steel and 2 were related to concrete foundation footings.

The structural omission changes had 29 changes of which 9 changes were due to the addition of piling that cost a total of $379,954. The largest change was for $232,451 to increase the length of existing piling, which resulted after the addition of test piles and a load test. The other structural area was the addition to a concrete foundation which

accounted for five changes, which cost $74,377. The most expensive of these was the cost to provide construction joints in the foundation.

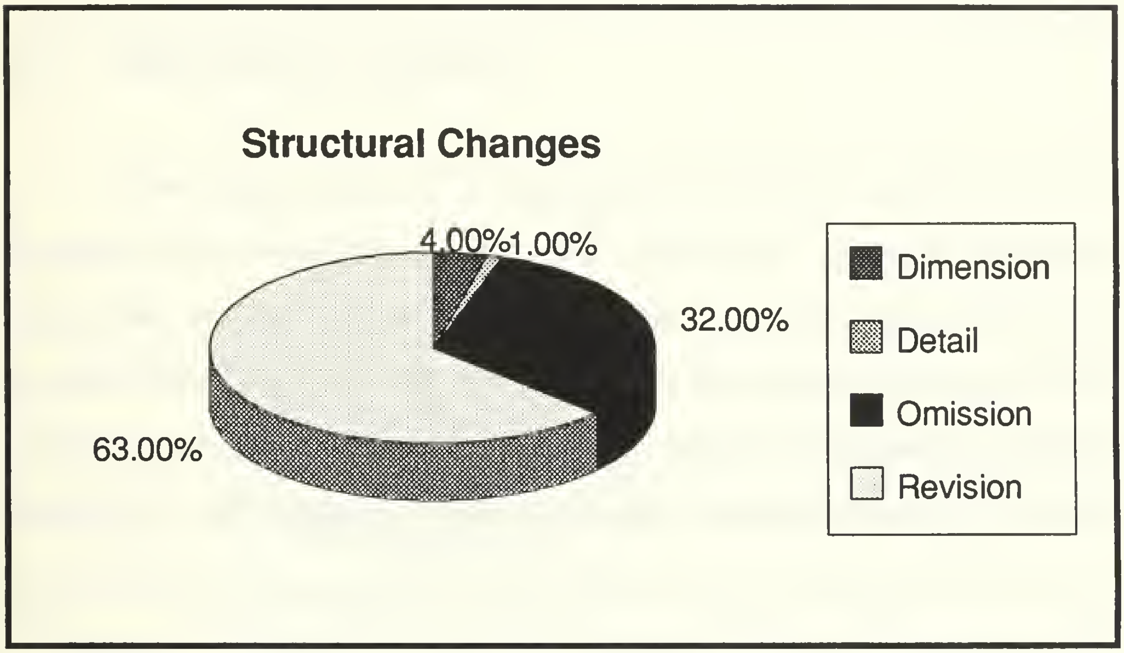

Figure 5-9: Percent of Cost for Structural Changes

The structural revision changes had the most expensive changes. Most of these changes were performed for the berthing improvements at Mayport, Florida. The single most expensive change was for repairing a sheet pile wall that cost $285,300. This contract also had 2 changes for revising the alignment of the bulkhead wall which cost $177,837 for both and 2 changes to revise the concrete bulkhead which cost $151,007 for both. Besides this contract, there were 2 other changes that were extremely costly, one of which required the demolition and replacement of an antenna foundation which cost

$217,245 and another change that revised the type of coatings on the concrete foundation, which cost $149,395.

5.5 MECHANICAL CHANGES

There were a total of 79 changes at a total cost of $674,712. A summary of the breakdown is shown in Figure 5-10. Omission changes accounted for the most, at 46%, but revisions cost the most at 49% of the total cost. Figures 5-11 and 5-12 show the percent of changes and cost for mechanical changes. An average cost for a mechanical change was $8,541 with revisions having the largest average (at over $13,000).

Reason for Change	No. of Changes	% of Changes	Total Cost	% of Cost	Avg. Cost per Change
Dimension	3	4	$25,660.00	4	$8,553
Detail	3	4	$6,840	1	$2,280
Interference	12	15	$99,815	15	$8,318
Omission	37	46	$210,662	31	$5,694
Revision	24	31	$331,735	49	$13,822
Total =	79	100	$674,712	100	$8,541

Figure 5-10: Mechanical Changes

The mechanical dimension and size changes had 3 changes all involving size changes. The largest of these was to increase the thickness of galvanized sheet metal panels, which cost $19,200.

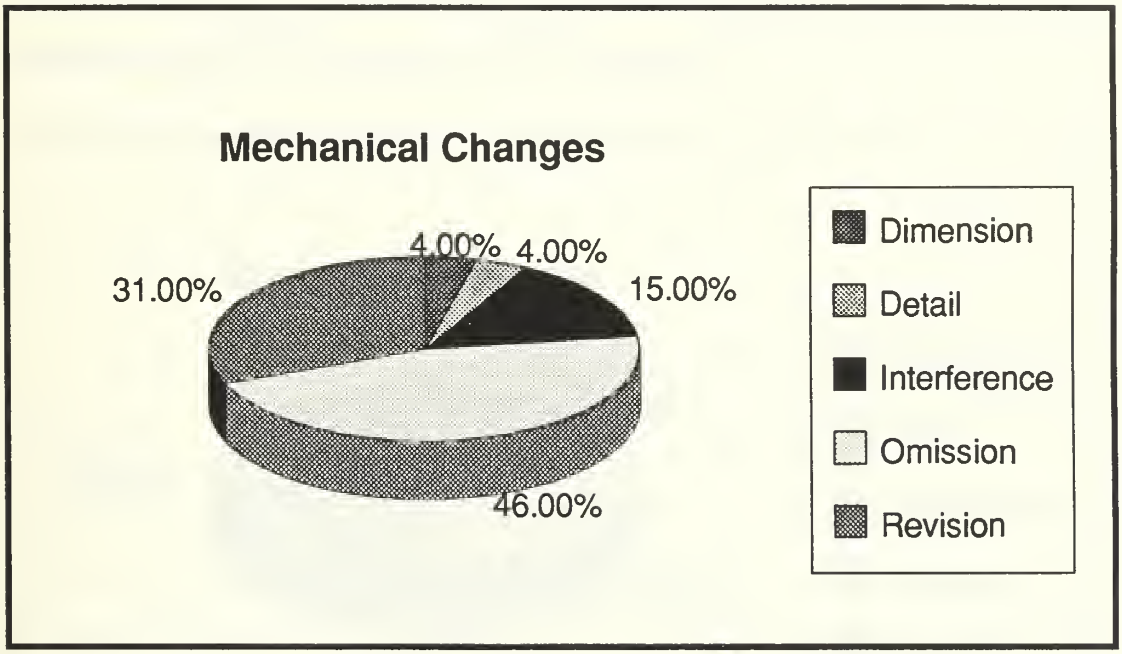

Figure 5-11: Percent of Mechanical Changes

The mechanical detail changes also involved 3 changes which were not related. The largest of these required the extension of supports for roof mounted HVAC equipment which cost $5,188. This was due to a coordination problem where the structural engineer did not know the required lengths of the supports necessary to provide adequate clearance under the unit.

The mechanical interference changes required re-routing and relocation of utility lines. Re-routing piping, which included gas lines, water lines and steam lines, accounted for 9 of the 12 changes. This piping was located both underground and overhead. The remaining 3 changes were for re-routing of HVAC ductwork.

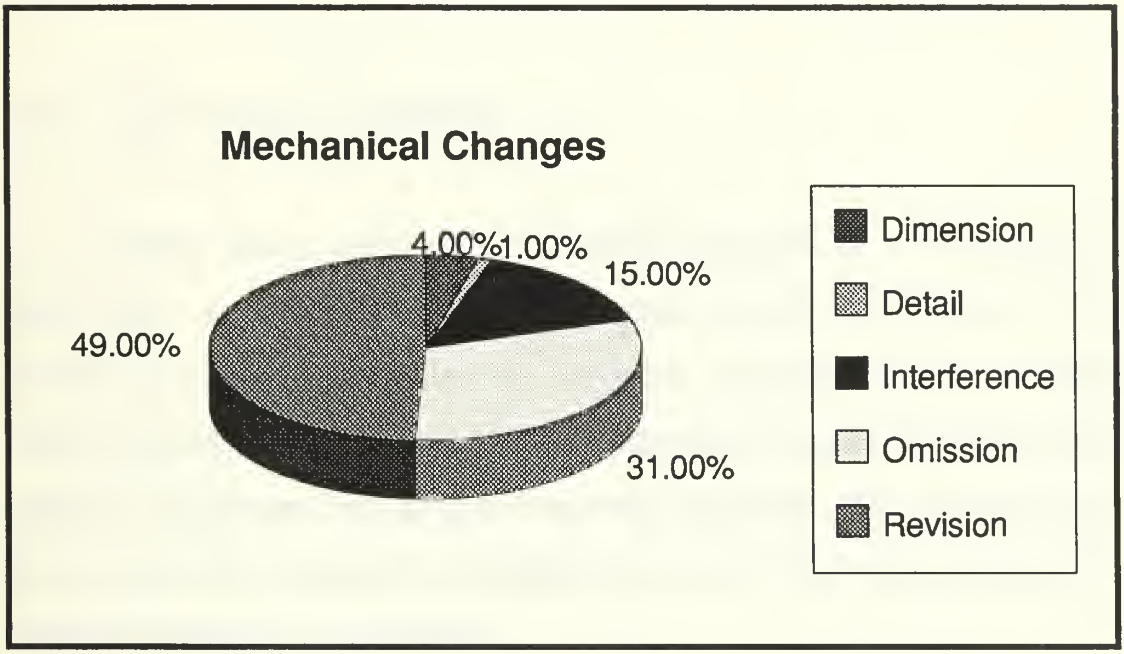

Figure 5-12: Percent of Cost for Mechanical Changes

The mechanical omissions and architectural omissions had the largest number of changes (37) for all of the categories. These changes included additions of piping, valves, ductwork and mechanical accessories. The most costly change involved adding 233 sprinkler heads to the fire protection system due to a revision of the shop drawings by Southern Division.

The mechanical revision changes involved 24 changes that had the highest cost of all the mechanical changes. The most common change was for modifying piping systems, which could have involved re-routing of pipe due to interferences. The most costly change was to change the type of pipe from carbon black steel to stainless steel, which cost $95,000.

5.6 ELECTRICAL CHANGES

There were a total of 52 electrical changes at a total cost of $360,309. A summary of the breakdown is shown in Figure 5-13. Omission changes accounted for the most changes at 50% and also cost the most at 67% of the total cost. Figures 5-14 and 5-15 shows the percent of changes and cost for electrical changes. The average cost for an electrical change was $6,929 each with omissions having the largest average (at over $9,000).

Reason for Change	No. of Changes	% of Changes	Total Cost	% of Cost	Avg. Cost per Change
Dimension	4	8	$10,390.00	3	$2,598
Detail	2	4	$12,736	4	$6,368
Interference	2	4	$2,735	1	$1,368
Omission	27	50	$243,783	67	$9,029
Revision	17	34	$90,665	25	$5,333
Total =	52	100	$360,309	100	$6,929

Figure 5-13: Electrical Changes

The electrical dimension and size changes involved 4 changes of which 2 involved increasing the size of a circuit breaker. The 2 remaining changes involved changing the size of a transformer and the type of a light fixture.

The electrical detail changes involved 2 changes, one of which was the modification of an electrical light fixture detail and the other was a change in the wiring schematic detail.

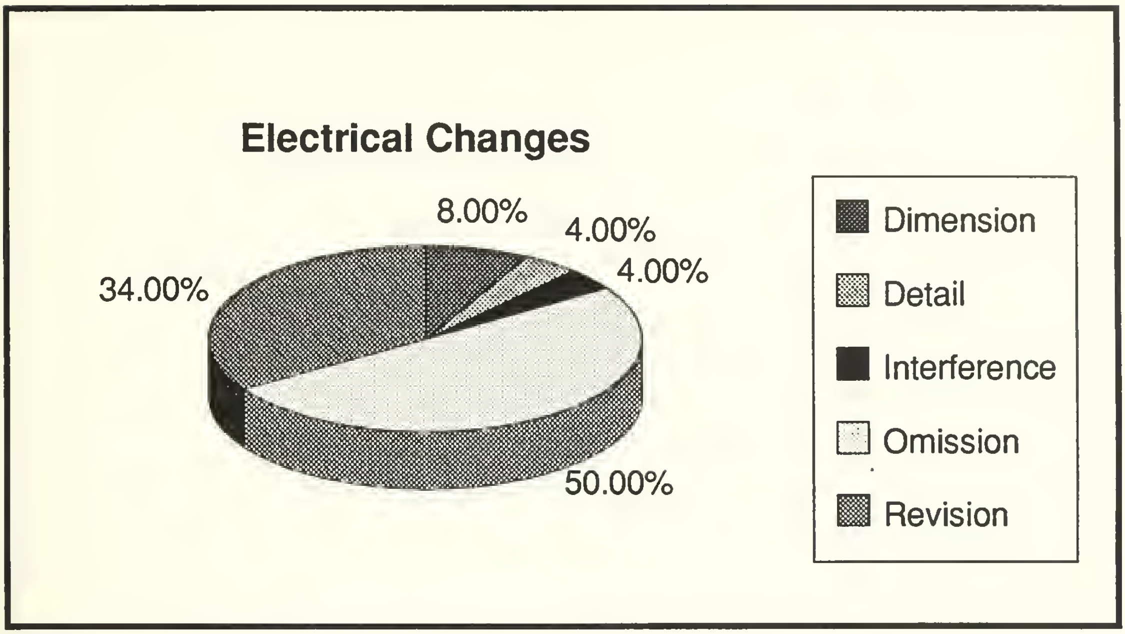

Figure 5-14: Percent of Electrical Changes

The electrical interference changes involved 2 changes, one which required the changing of an elevation of an underground electrical ductbank and the other for a revision of a structural support to provide clearance for a circuit breaker.

The 27 electrical omission changes accounted for the most changes in the electrical section. The most common changes were the addition of circuit breakers of which there were 7 changes costing a total of $83,784. Some of the other areas included the addition of wiring and conduit (5 changes), additional disconnect switches (3 changes), additional feeders (2 changes) and additional light fixtures (2 changes).

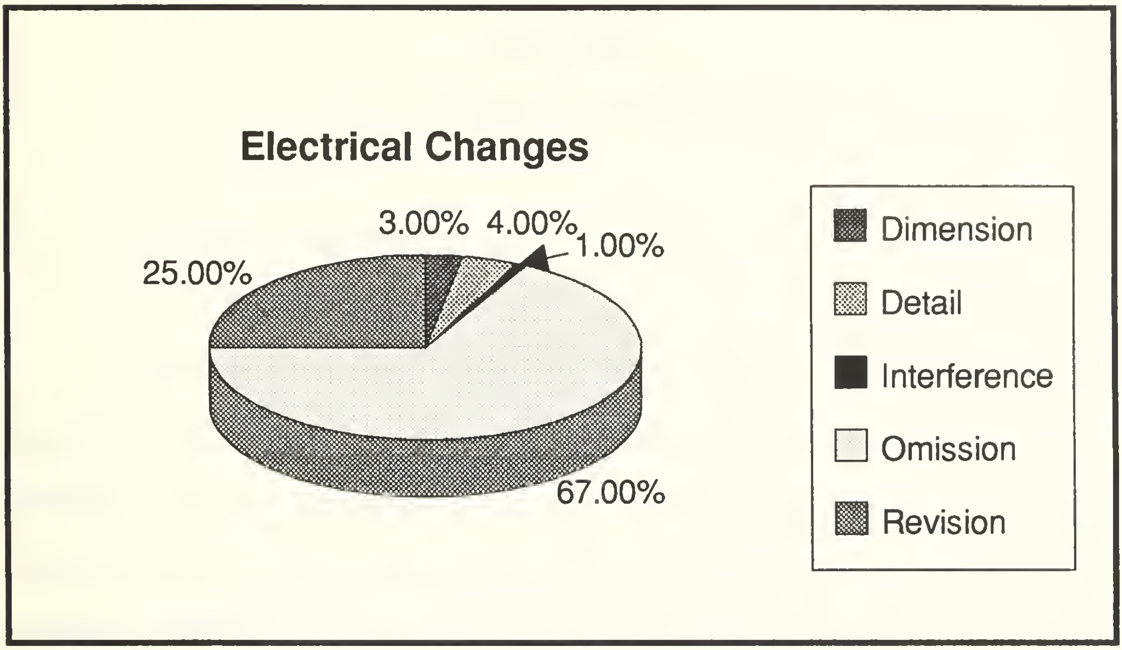

Figure 5-15: Percent of Cost for Electrical Changes

The electrical revision changes had many different types of electrical revisions. The most costly change was due to the re-routing of an electrical ductbank. Other examples of changes included relocating receptacles, changing the size and type of conduit, tracing control circuits, relocation of fire alarms and revising a telephone riser.

CHAPTER 6
DISCUSSION OF RESULTS

6.1 SUMMARY OF RESULTS

The design changes numbered from a low of 2 for the Hazardous Mat/Flam Warehouse at Gulfport, Mississippi, (which cost a total of $5,652), and the Ammunition Storage Magazines, Phase I, Ingleside, Texas, (which cost a total of $2,724), to a high of 47 for the Ship Berthing Improvements at Naval Station, Mayport, Florida, (which cost a total of $994,593). The 23 projects averaged 13 design related changes per project. The design change order rate for each project was calculated by dividing the initial construction contract award amount into the total cost of all design changes for that project. The design change order rate ranged from a low of 0.1% to a high of 14.1%. The design change order rate for each project is listed in the appendix on page 57. The average design change order rate for all the projects combined was 2.8%. There were 4 projects for which design related changes exceeded 6% of the initial construction contract award amount.

A comparison of the changes according to which discipline was responsible for the design change is shown in Figure 6-1. As can be seen, the mechanical discipline accounted for the most changes (79) and the structural discipline changes cost the most ($1,666,986). The

structural changes averaged over $29,000 each which was 3 to 5 times higher than the average of the other disciplines. The average cost for all changes was $11,474 each.

Discipline	No. of Changes	% of Changes	Total Cost	% of Cost	Avg. Cost per Change
Architectural	60	21	$355,499.00	11	$5,925
Civil	44	15	$292,841	9	$6,655
Structural	57	20	$1,666,986	49	$29,245
Mechanical	79	26	$674,712	20	$8,541
Electrical	52	18	$360,309	11	$6,929
Total =	292	100	$3,350,347	100	$11,474

Figure 6-1: Summary of Changes by Discipline

Figures 6-2 and 6-3 show the percent of changes and cost for each engineering discipline. Each of the disciplines had a narrow distribution of changes. Three of the disciplines; architectural, civil and electrical had almost the same number of changes and cost for changes.

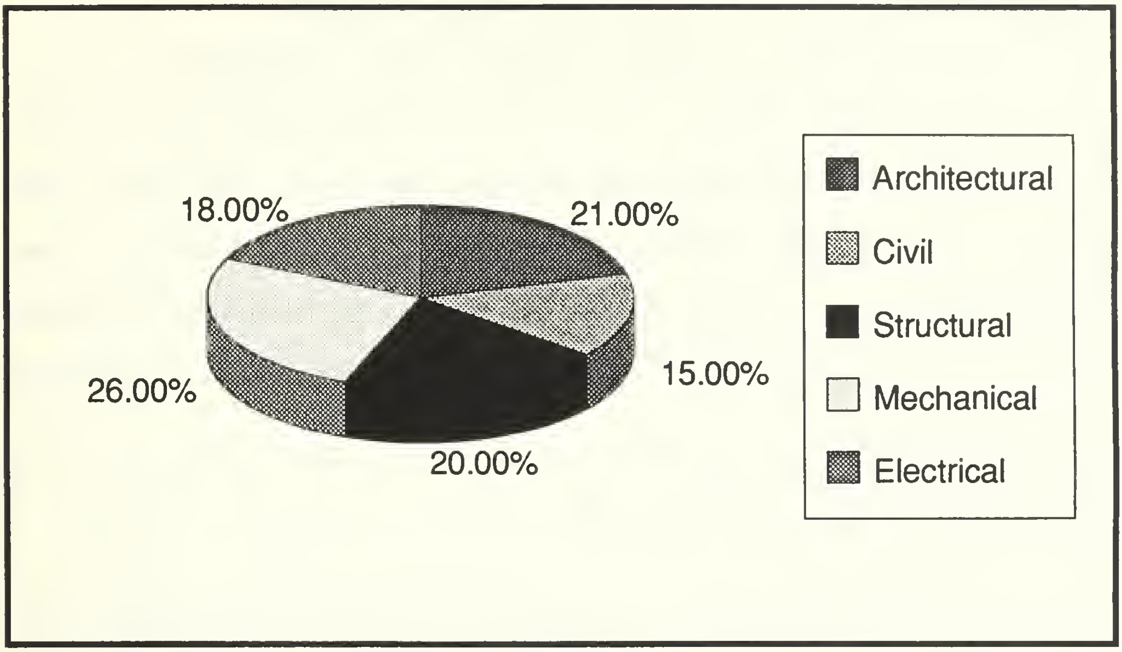

Figure 6-2: Percent of Changes by Discipline

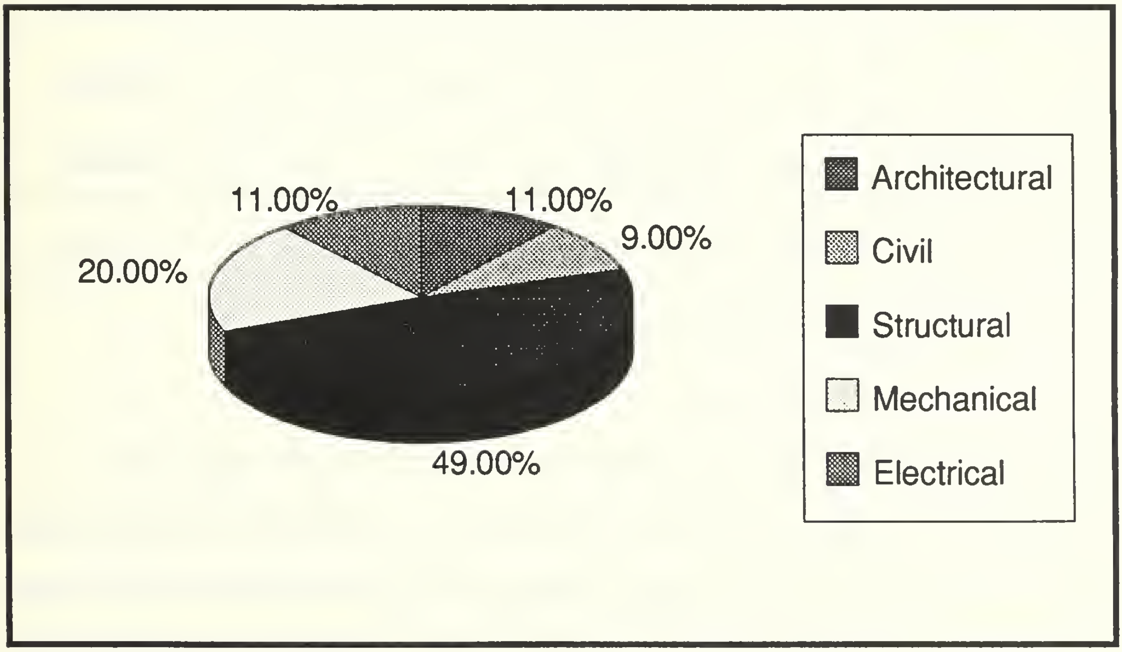

Figure 6-3: Percent of Cost for Changes by Discipline

A comparison of the changes based on the reason why the change was made is shown in Figure 6-4. Omissions accounted for the most changes at 145 or 49% of the total, and the most costly changes were due to revisions. Figures 6-5 and 6-6 show the percent of changes and cost by reason for the change. The revisions also averaged a much higher cost of $19,112.

Reason for Change	No. of Changes	% of Changes	Total Cost	% of Cost	Avg. Cost per Change
Dimension	22	8	$116,357.00	3	$5,289
Detail	14	5	$50,153	2	$3,582
Interference	17	6	$106,895	3	$6,288
Omission	145	49	$1,284,036	37	$8,855
Revision	94	32	$1,792,906	55	$19,073
Total =	292	100	$3,350,347	100	$11,474

Figure 6-4: Summary of Changes by Reason

The omission and revision reasons for the changes combined accounted for over 90% of the cost of all the changes. In order to reduce this cost and lower the design change order rate, the A/E must concentrate on eliminating those changes resulting from omissions and revisions of the designs. To lower the cost of omissions, the following

areas of design must be improved: coordination of doors and door hardware, adequate length and number of concrete piling which is probably related to a better knowledge of the existing soil conditions, and complete mechanical systems including all necessary piping, valves, ductwork and accessories. To lower the cost of revisions, the following areas of design must be improved; again, better knowledge of existing soil conditions for earthwork and backfill, better knowledge of the condition of existing structures, especially waterfront structures, and elimination of interferences among various mechanical systems.

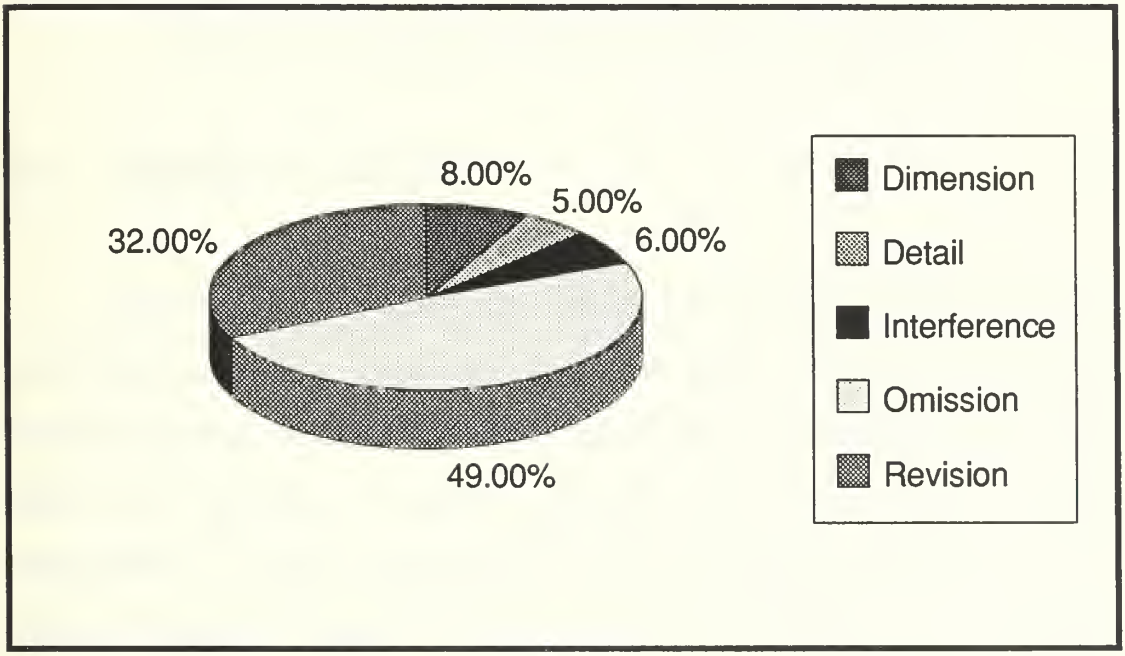

Figure 6-5: Percent of Changes by Reason

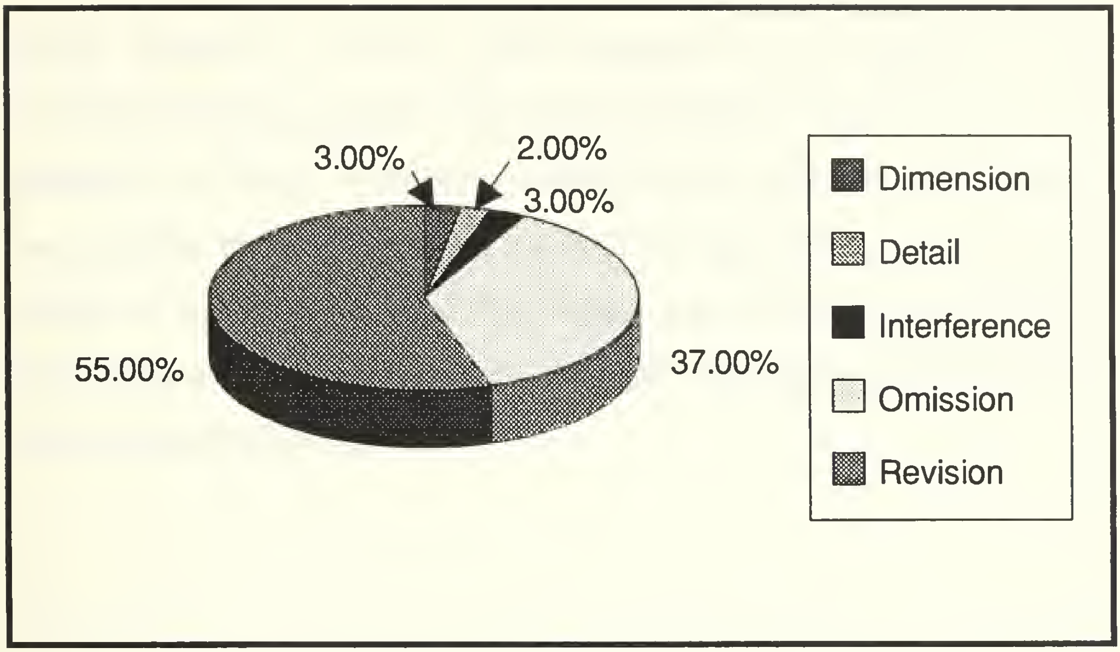

Figure 6-6: Percent of Cost for Changes by Reason

6.2 TIMING OF CHANGES

Another area of concern in regards to the design related changes is the timing of the change during construction. Since these changes occurred during construction, their impact on the contractor could have been far reaching. These changes may cause cost increases attributable to some combination of the following: productivity loss, delays, materials wasted in rework, equipment standby cost, equipment and labor spent in removal of completed work and nonproductive periods during redirection of work.[13] Of the 23 projects, 17 projects had

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[13]Construction Industry Institute Cost/Schedule Controls Task Force, The Impact of Changes on Construction Cost and Schedule, Publication 6-10 (Austin, TX: Construction Industry Institute, 1990), p. 7.

design changes in which a time extension was required for the completion of the project and the other 6 projects did not require a time extension. A listing of the time extensions for each project is listed in the appendix on page 57. The project for Ship Berthing Improvements located in Mayport, FL. had the largest time extension of 411 days. These time extensions also resulted in indirect cost that were not shown in the cost of the changes.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

1. Design changes averaged 2.8% of the initial construction contract amount which is almost half of the maximum design fee allowed.

2. The average cost for structural changes was $29,245. This is over 4 times the average of the remaining disciplines which averaged $7,163.

3. The time extensions granted for all the projects totaled 1275 days. The higher the design modification rate the more days allowed for a time extension. These delays also resulted in an increased indirect cost of construction due to the additional overhead expenses of the ROICC staff that was administering the contract. In addition, these delays can also result in additional cost for the customer and their dissatisfaction with the ROICC's contract administration.

7.2 RECOMMENDATIONS

1. The "Redicheck Plan and Specification Review" and the NAVFAC P446 "Constructability Reviews" should be utilized since they would have identified most of the design changes during the review process. The constructability review performed by the ROICC office should use the NAVFAC publication if not already doing so. The ROICC offices need to understand the importance of the review effort and use very experienced personnel for the review. The ROICC office must be given adequate time to perform the review and they must allocate enough time to do a thorough review.

2. The Navy must make sure that adequate funds are available for the design so not to have to delete or reduce the scope of the A/E's design effort. Further research should be done in order to see if the 6% design fee cap is adequate in purchasing quality deign services. Even though modernization of the design tools used by A/E's such as 3-D CAD systems may result in lower design cost, the 6% fee may still not be adequate in compensation for high quality designs. The criteria for selection of an A/E firm should include consideration of the use of a 3-D system for design since it will reduce the number of omissions, revisions, and interferences that are currently occurring.

3. For reviewing plans and specifications, more emphasis should be placed in checking the following areas: Architecture - coordination of doors and door hardware , Civil - better knowledge of existing soil conditions, Structural - better coordination of structural design for projects involving rehabilitation of existing facilities, Mechanical - check for piping interferences for both existing and new piping, and Electrical - ensure that the all the wiring diagrams have corresponding circuit breakers.

4. A review of the establishment of proper modification coding will allow a more realistic tracking of the changes with the CMS system. The continuous use of the "UNFO" code should be curtailed except for those truly unforeseen conditions. Some of the contracts reviewed did not have any changes coded "DSGN" and some of the "UNFO" changes appeared to be design related and should not have been unforeseen when the design was performed. The opposite occurred on some contracts where all the changes were coded "DSGN." It appeared there were no site visits to the job, the A/E was not competent, or someone decided to change the scope of the project.

5. There were four projects which had change order rates that exceeded 6%. These four projects involved rehabilitation of existing facilities and were complex in nature. Future projects of this type should be given special attention to ensure an adequate design is performed.

CHAPTER 8

APPENDIX

SUMMARY OF PROJECT DATA

CONTRACT NUMBER	LOCATION	PROJECT	INITIAL AWARD AMT.
84-0182	Albany, GA	Ventilation Improvements	$3,807,714
86-0096	Amarillo, TX	Reserve Training Center	$2,799,970
87-0412	Andros Island	Bachelor Civ. Quarters	$2,802,000
86-0427	Beaufort, S.C.	B.E.Q. Modifications	$2,052,135
87-0281	Charleston NS	B.E.Q.	$8,109,000
86-0263	Charleston NSC	Provisions Warehouse	$4,540,000
85-0152	Charleston NSY	Power Plant Modifications	$2,720,000
85-0604	Charleston NWS	Consolidated Brig	$14,028,000
86-0020	Gulfport, MS	Haz Mat/Flam Warehouse	$2,633,000
86-0073	Hawkinsville, GA	Space Surveillance Antenna	$2,144,000
86-0729	Ingleside, TX	S.I.M.A.	$5,532,000
88-0045	Ingleside, TX	H.Q. Support	$2,857,000
88-0091	Ingleside, TX	Warehouse	$3,415,384
86-0731	Ingleside, TX	B.E.Q.	$5,498,000
85-0631	Jax NADEP, Fl	Engine Rework Facility	$10,223,000
86-0875	Jax NAS	Optical Trainer Building	$6,079,000
86-0090	Jax NSC	Storage Facility	$3,741,000
86-0112	Kingsville, TX	T-45 Sqn. Maint. Facility	$7,149,000
83-0216	Mayport NS, FL	Ship Berthing Improvements	$9,665,000
87-0011	Mayport NS, FL	Industrial Waste Treatment	$2,795,955
83-0232	Memphis, TN	Brig	$2,957,500
84-1010	Pensacola, FL	Aircraft Struct. Repair Facility	$8,213,000
84-0004	Shaw AFB, S.C.	Alter U.E.P.H.	$4,103,236

SUMMARY OF PROJECT DATA (continued)

CONTRACT NUMBER	NUMBER OF DESIGN CHANGES	ARCHITECTURAL CHANGES COST	CIVIL CHANGES COST
84-0182	7	$0	$6,507
86-0096	8	$1,046	$16,097
87-0412	9	$8,664	$63,357
86-0427	5	$14,199	$0
87-0281	8	$6,067	$0
86-0263	12	$8,671	$28,325
85-0152	9	$0	$0
85-0604	37	$85,435	$12,872
86-0020	2	$5,651	$0
86-0073	7	$0	$21,805
86-0729	14	$23,503	$357
88-0045	2	$947	$1,777
88-0091	6	$1,731	$0
86-0731	12	$44,115	$16,007
85-0631	25	$6,734	$3,112
86-0875	14	$14,389	$15,258
86-0090	14	$41,815	$25,971
86-0112	11	$29,823	$0
83-0216	47	$0	$26,354
87-0011	14	$0	$29,319
83-0232	8	$12,284	$0
84-1010	20	$4,425	$25,723
84-0004	4	$46,000	$0

SUMMARY OF PROJECT DATA (continued)

CONTRACT NUMBER	STRUCTURAL CHANGES COST	MECHANICAL CHANGES COST	ELECTRICAL CHANGES COST
84-0182	$0	$63,602	$6,129
86-0096	$0	$11,456	$1,090
87-0412	$13,790	$14,759	$0
86-0427	$266,370	$0	$0
87-0281	$2,312	$29,828	$3,990
86-0263	$79,669	$33,897	$1,200
85-0152	$0	$51,987	$130,043
85-0604	$5,582	$38,274	$72,373
86-0020	$0	$0	$0
86-0073	$280,963	$0	$0
86-0729	$20,385	$14,953	$2,875
88-0045	$0	$0	$0
88-0091	$0	$5,392	$0
86-0731	$0	$40,558	$846
85-0631	$199,281	$56,169	$23,082
86-0875	$12,081	$15,132	$18,179
86-0090	$56,174	$9,306	$543
86-0112	$7,672	$16,137	$19,281
83-0216	$713,171	$215,334	$39,734
87-0011	$0	$23,914	$21,898
83-0232	$4,036	$4,500	$3,246
84-1010	$5,500	$24,014	$12,542
84-0004	$0	$5,500	$3,258

SUMMARY OF PROJECT DATA (continued)

CONTRACT NUMBER	TOTAL COST FOR CHANGES	DESIGN CHANGE ORDER RATE (%)	TIME EXTENSION
84-0182	$76,238	2	79 days
86-0096	$29,689	1	13
87-0412	$100,570	3.6	84
86-0427	$280,569	13.7	206
87-0281	$42,197	0.5	5
86-0263	$151,762	3.3	62
85-0152	$182,030	6.7	103
85-0604	$214,536	1.5	14
86-0020	$5,651	0.2	9
86-0073	$302,768	14.1	30
86-0729	$62,073	1.1	7
88-0045	$2,724	0.1	1
88-0091	$7,123	0.2	0
86-0731	$101,526	1.8	0
85-0631	$288,378	2.8	0
86-0875	$75,039	1.2	0
86-0090	$133,809	3.6	61
86-0112	$72,913	1	0
83-0216	$994,593	10.3	411
87-0011	$75,131	2.7	122
83-0232	$24,066	0.8	51
84-1010	$72,204	0.9	17
84-0004	$54,758	1.3	0

CHAPTER 9

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VITA

Michael Keith Westmoreland was born in Wichita Falls, Texas on August 30,1960, the son of Juanita Helen Westmoreland and Alford Dean Westmoreland. After graduating from Wichita Falls High School, he attended The University of Texas at Arlington where he received his Bachelor of Science in Civil Engineering in May of 1983. While attending college, he worked for Wier and Associates, Inc., an engineering firm in Arlington, Texas.

After graduation, he went to work for Biggs and Mathews, Inc., as a design engineer for residential and commercial development. In 1985, he entered the United States Navy as a Civil Engineer Corps Officer. His first assignment was as the Assistant Public Works Officer at Chase Field Naval Air Station in Beeville, Texas. His responsibilities were for the day-to-day operations of public works. In 1989, he was reassigned as the Assistant Resident Officer in Charge of Construction at the new Homeport in Ingleside, Texas. He was the project manager in charge of administration of the construction contract to build the Pier and Wharf as well as a Ship Maintenance Building and an Ammunition Storage Bunker. He entered the Graduate School of the University of Texas at Austin in January 1991.

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